Inputs for 99 Technology Inventory

Objective and Description

The objective is to develop enabling technology to characterize the solid-liquid interface during directional solidification to unprecedented levels with real-time measurement hardware.

Existing x-ray imaging hardware is combined with compact Seebeck furnaces and thermal profiling hardware, under development, to accomplish the measurements. Furnace thermal profiles are continuously measured in addition to the sample characteristics.

Benefits

The velocity, temperature gradient, morphology and undercooling of the solid-liquid interface greatly influence the material properties resulting from directional solidification. Having the ability to measure these properties during solidification greatly enhances the ability to identify important parameters and to characterize the interface under better-measured and controlled conditions. Real-time thermal profiling of the furnace adds an additional benefit to the overall measurements and interpretation of the results.

State of the Art (Including Metrics)

The previously developed X-ray Transmission Microscope, XTM, is state of the art and unique for x-ray imaging, as reported by W. Kaukler , P. Curreri, et al. To our knowledge, the Compact Seebeck Furnaces developed so far are the smallest units that perform directional solidification while measuring interface undercooling, as reported by S. Sen, et al. The thermal profiling hardware, under development, appears to be state of the art for applications to furnace and sample profiling also.

Milestones and Status

Two generations of compact Seebeck furnaces have been developed. The lower temperature version demonstrated that a furnace small enough to be incorporated with x-ray imaging hardware was feasible. It was verified by solid-liquid Seebeck measurements on previously reported samples. The second-generation furnace demonstrated that a higher temperature design was possible, and it has been used to measure aluminum alloys, for which Seebeck coefficients of the liquid are presently unknown. Encouragingly, the data characteristics for the aluminum alloys resemble those for the low temperature samples. Thermal profiling hardware, under development, has been used to profile the second-generation furnace, verifying the expected characteristics, and identifying an early design flaw that was corrected. Separate thermal profiling of a tin sample gave good results for slightly non-uniform heating and isothermal cooling of the sample. A length of 1.0 cm of the sample was well profiled and demonstrated appreciable undercooling and recalescence, as shown in the attached figure. Thermal profiling of samples with high temperature gradients requires further hardware development to be satisfactory, and this is progressing. A third generation Seebeck furnace is under development, which corrects weaknesses in earlier designs and will combine all measurement capabilities into one unit. Techniques for determining the Seebeck coefficients of very reactive molten aluminum alloys are under study. Development is in the third year of a four-year term.

Tin sample was heated above the melting point of 231.9 °C and then passively cooled through recalescence.